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Relation Between Universal Extractants and Soybeans (*Glycine max* L.) Response to P and K Application under Greenhouse Conditions

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ABSTRACT

A study was conducted with the objective to evaluate the relation between universal extractants tested and soybean response to P and K fertilizer application in a pot experiment. Surface soil samples were collected from Damot Sore, Boloso Bombe, Damot Pulasa, Humbo, Haramaya, Babile and Dire Dawa sites. The treatments were arranged in a factorial completely randomized design with three replications. Among the universal extractants tested for correlation with P concentration in the leaves of the soybean, 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3 and 0.02 M SrCl₂ to 0.025 M citric acid extractants showed significant correlation at (p<0.05) significance level. Therefore, 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3 and 0.02 M SrCl₂ to 0.025 M citric acid extractants could be used as a suitable method for determination of P in soils of the studied areas. The AB-DTPA extractant showed very strong and positive correlation coefficients at p<0.01 significance level than the other extractants tested for K concentration in the leaves of the plant. However, K concentration values of leaves of the plant were also positively and significantly correlated at p<0.05 with K concentration of soils obtained by 0.02 M SrCl₂, Mehlich 3, 0.02 M SrCl₂ to 0.025 M citric acid, 0.02 M SrCl₂ to 0.05 M citric acid, 0.02 M SrCl₂ to 0.075 M citric acid and 0.02 M SrCl₂ to 0.1 M citric acid and extractants tested in this study. Therefore, any of these extractants could also be used to predict K in soils of the studied areas. However, further study is recommended to confirm these findings under field conditions.

Key words: Greenhouse, P and K concentration, soybean, universal extractant

INTRODUCTION

The introduction of a universal extractant in routine soil testing is attractive because it generates options for optimization of laboratory management and the procedure is often cheaper as compared to a series of conventional single nutrient element extraction procedures (Van Raij, 1994). To prove the advantages of a soil test in field conditions is a long and costly process because of the impact of variable and hardly controllable factors of the site and years. The fastest method of correlation research is pot experiments with a larger set of different soils under controlled cultivation conditions of the growing of a test plant when the impact of uncontrollable variables may be eliminated (Dahnke and Olson, 1990).

Soybean is one of the most important crops in the world and has higher protein content than any other pulse (Giller and Dashiell, 2007). Soybean is cultivated in tropical, subtropical and temperate areas, often on soils low in phosphorus (P) because of intensive erosion, weathering and strong P fixation by free Fe and Al oxides (Sample *et al.*, 1980; Stevenson, 1986). Unfortunately, over 50% of the world's potential arable land surface is composed of acid soils mostly distributed in developing countries (Kochian *et al.*, 2005). This restricts the production of soybeans and other legumes due to their sensitivity to acid soil infertility. Stoorvogel *et al.* (1993) showed that there are high nutrient depletion rates in N, P and potassium (K) in different farming systems in 38 sub-Saharan African countries including Ethiopia. Moreover, the utilization efficiency of phosphatic fertilizers by plants is only 20-25% largely due to its chemical fixation in soil (Hedley *et al.*, 1995). Although, mineral toxicity in acid soils can be ameliorated by the use of lime, the extra cost will further limit the preference of the poor resource farmers. Ezech *et al.* (2007) noted that combining sound management practices with genetic tolerance to low pH could ameliorate negative impact of acid soil stress on crop performance.

The Ethiopian soils, similar to the other agricultural soils of the tropics are generally low in available P. Several research results (Lupwayi and Haque, 1996; Boke, 2004) indicated that most of the highland soils of Ethiopia are inherently P deficient and hence, it is one of the limiting nutrient elements in crop production in the region. Phosphorus supplementation can enhance plant growth by increasing the efficiency of biological nitrogen fixation, enhancing the availability of macronutrients such as N, P, K, Ca and Mg (Makoi *et al.*, 2013).

Potassium is an essential and major nutrient for crop production (Alfaro *et al.*, 2003; Zhang *et al.*, 2011). The importance of K as an essential nutrient for growth and development of crop plants is well known. Adequate supply or balance of K with these nutrients determines response of crop plants to N and P. Potassium regulates osmotic potential in plants and reduces incidence of diseases (Fageria, 2009). Plants can take up both exchangeable and non-exchangeable forms of K. Bhonsle *et al.* (1992) suggested that fixed or non-exchangeable forms of K can even be the main source of K for plants.

So far, no study has been done on the correlations between universal extractants and soybean response to P and K application in Ethiopian soils. Therefore, the objective of this study was to evaluate the relation between universal extractants proposed and soybean response to P and K application under greenhouse conditions.

MATERIALS AND METHODS

Description of the study area: The study was conducted in some selected parts of Ethiopia. These areas were Eastern Harargie zone (Babile and Haramaya districts), Wolaita zone (Bolosso Bombe, Damot Pulasa, Damot Sore and Humbo districts) and Dire Dawa Administrative Council as shown in Fig. 1.

Soil sampling and sample preparation and analysis: A bulk soil sample was taken from the top (0-20 cm) from alkaline and neutral soils of Eastern Harargie zone (Babile and Haramaya district), acidic soils of Wolaita zone (Bolosso Bombe, Damot Pulasa, Damot Sore and Humbo districts) and moderately alkaline soils of Dire Dawa Administrative Council. The soil was air dried, ground and passed through a 2 mm sieve and analyzed for selected chemical and physical properties according to standard laboratory procedures.

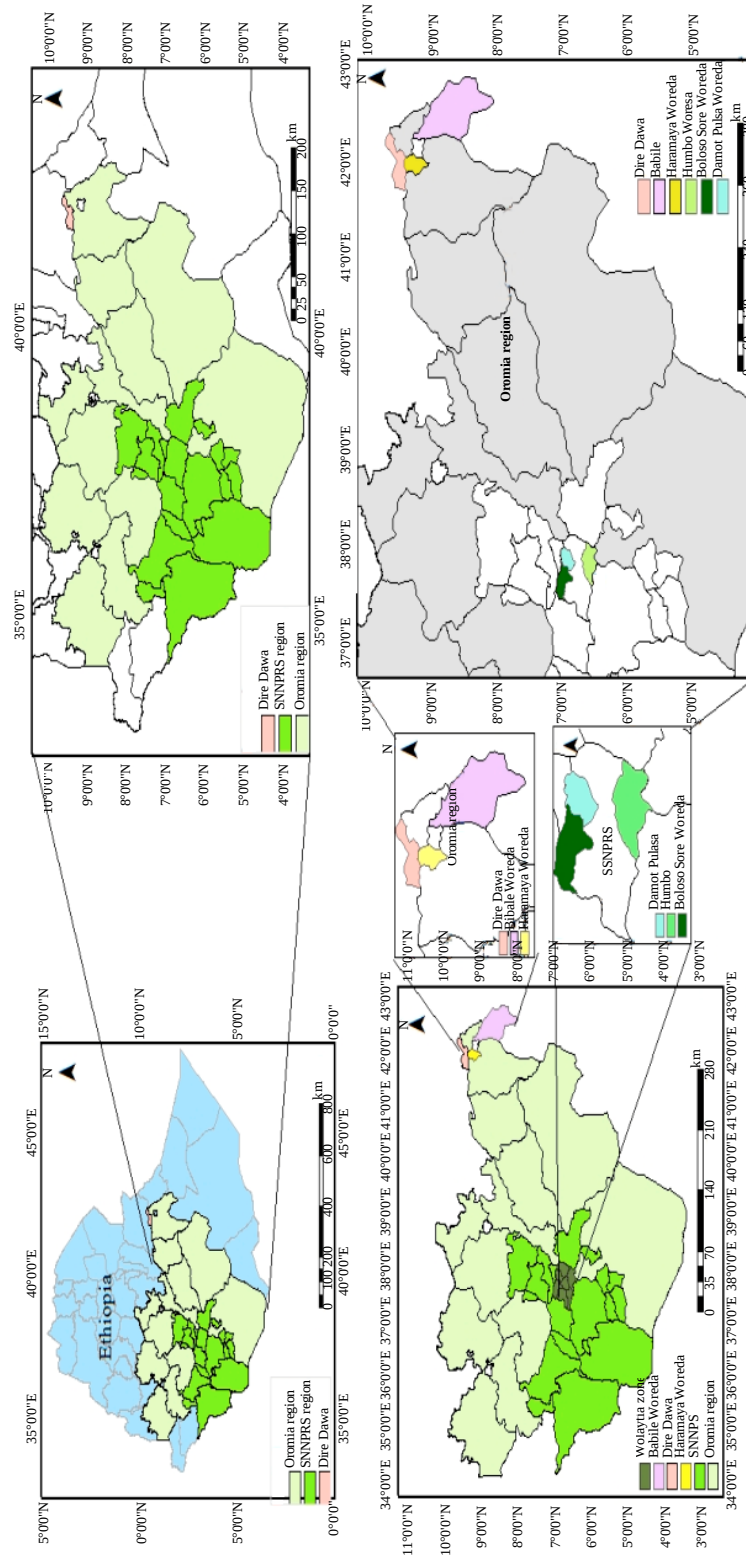


Fig. 1: Location map of the study area

Analysis of soil chemical properties: Soil pH was measured potentiometrically in H₂O and 1 M KCl solution at the ratio of 1:2.5 for soil, H₂O and soil, KCl solutions using a combined glass electrode pH meter (Van Reeuwijk, 1992; Freese *et al.*, 1995). The exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution and titrating with NaOH solution (Anderson and Ingram, 1993). Electrical conductivity of the soil samples were measured using conductivity meter (Van Reeuwijk, 1992).

Determination of P and K using universal extractants: The available P and exchangeable K concentrations of the soils samples in the studied areas were determined using 0.01 M CaCl₂, 0.02 M SrCl₂, 0.01 M BaCl₂, 0.1 M BaCl₂, Mehlich 3, AB-DTPA, 0.02 M SrCl₂ to 0.025 M citric acid, 0.02 M SrCl₂ to 0.05 M citric acid, 0.02 M SrCl₂ to 0.075 M citric acid and 0.02 M SrCl₂ to 0.1 M citric acid extractants following standard procedures.

Analysis of plant tissue samples: Plant tissue sample preparation and analysis was done following procedure for plant tissue analysis using wet digestion procedure (Okalebo *et al.*, 2002). Just before flowering (after 60 days) ten-twenty fully developed leaves at the top of the plant was sampled for analysis of P and K (Jones, 2003). Plants samples were washed with distilled water and oven dried at 70°C. The dry weight of the plant sample was determined by taking above ground biomass of the plant. A total of 336 samples of soybeans leaves were analyzed for P and K concentrations in the leaves of the plant following standard laboratory procedures.

Pot experiment: A pot experiment was arranged to disclose the effects of the treatments applied. Four rates of P (0, 23, 46 and 69) kg P₂O₅ per ha in the form of TSP and four rates of K (0, 21.5, 43 and 64.5) kg of K₂O per ha in the form of KCl were thoroughly mixed to the respective bulk of soil before the soil is incorporated into the plastic container for each site. The soils also supplied with basal application of 18 kg N per ha (blanket application rate for soybeans in the pot experiment) in the form of urea (Wijnands *et al.*, 2011). For this pot experiment, composite soil samples with three replications which passed through a 5 mm sieve were mixed with all treatments applied. Then, three replicate samples of three kilogram soil sample weighted from each bulked soil to fill into each plastic container. The pots were watered approximately near to field capacity before sowing. The soils in the pots were maintained moist throughout the growing season approximately to field capacity. Four seeds of soybean were sown per pot and two plants were maintained per pot after germination. A total of 336 pots were used for the green house experiment conducted.

The pot experiment was conducted in the greenhouse using soybean (Awassa-95 variety, as a test crop) taken from Awasa Research Center. The variety Awassa-95 (G-2261) was released in 2003/2004 cropping season (ARC, 2004). The variety used was high disease resistant, matured earlier and high protein content. Four seeds of the test crop per pot were planted in October 2013 at Haramaya University green house and two plants were maintained per pot after germination.

Experimental design: The study was conducted in a factorial Completely Randomized Design (CRD) with three replications at Haramaya University greenhouse in one soybean cultivars (Awassa-95) and seven different representative soil samples for the studied areas.

Data analysis: Data recorded were subjected to the analysis of variance (GLM procedure) using Statistical Analysis System version 9.13 (SAS, 2004). The Least Significance Difference (LSD) test

was employed for the mean separation of different treatments that were found to be significantly different in statistical terms. The correlations coefficients were also determined by using the same software.

RESULTS AND DISCUSSION

Soil chemical properties: The pH (H₂O) values of soils varied from 4.75-8.22 (Table 1). The lowest (4.75) value was observed in Damot Sore, whereas, the highest (8.22) was found in Dire Dawa. The higher acidity of the soils of Damot Sore and Boloso Bombe districts are mainly due to the continuous application of nitrogen containing fertilizers for several years. Owuor *et al.* (1990) have reported that the increasing rates of nitrogenous fertilizers generally increase soil acidity. Ishibashi *et al.* (2004) have reported that nitrogenous fertilizers are known to produce H⁺ by the following reaction which is induced by soil bacteria:



Thus, during the application of these fertilizers to the soil, the rate of nitrification is reported to be higher and inorganic nitrogen may be rapidly converted to nitrate producing H⁺ which acidifies the soil. According to Donald (2012), the pH ranges of the soils in the studied areas are from very strongly acidic to moderately alkaline.

Soil pH measured in water was higher by about 0.8-1 unit than the respective pH values measured in KCl solution (Table 1). The low soil pH with KCl determination indicates the presence of substantial quantity of exchangeable hydrogen ion. According to Mekaru and Uehara (1972) and Anonymous (1993), high soil acidity with KCl solution determination showed the presence of high potential acidity and weatherable minerals. In all the sites ΔpH (pH (KCl)-pH (H₂O)) values were negative, ranging from -0.88 to -1.13. According to Uehara and Gillman (1981) negative ΔpH values are an indication of the presence of net negative charges in soils.

Electrical Conductivity (EC) of the soils ranged from 0.005-0.61 dS m⁻¹. According to Waskom *et al.* (2012), this range is categorized as non saline and implies that the soils are not salt affected. High amount of exchangeable acidity in Damot Sore and Boloso Bombe were observed. This could likely due to the presence of substantial amount of sesquioxides in acid soils aggravate soil acidity. According to Hazelton and Murphy (2007), exchangeable acidity in the two districts are categorized or rated as very high. This finding is in agreement with Lindsay and Walthall (1996) and Moore (2001) who reported that the solubility of Al containing minerals increase as the soil pH falls below 5.5 and suggested that the probability of Al toxicity to plants become higher.

Table 1: Soil pH and electrical conductivity of soils of the studied areas

Experimental site	pH (H ₂ O)	pH (KCl)	ΔpH	EC (dS m ⁻¹)	EA cmol(±) kg ⁻¹
Damot Sore	4.75±0.05	3.73±0.05	-1.02±0.03	0.005	3.53±0.05
Boloso Bombe	5.22±0.03	4.29±0.05	-0.93±0.03	0.110	3.06±0.03
Damot Pulasa	5.73±0.05	4.72±0.04	-1.01±0.09	0.090	-
Humbo	6.26±0.05	5.13±0.05	-1.13±0.10	0.070	-
Haramaya	7.05±0.08	6.20±0.10	-0.85±0.10	0.110	-
Babile	7.63±0.05	6.73±0.06	-0.90±0.10	0.110	-
Dire Dawa	8.22±0.02	7.34±0.03	-0.88±0.04	0.610	-

ΔpH: Change in pH, EC: Electrical conductivity, EA: Exchangeable acidity

Table 2: Concentrations of P (mg kg⁻¹) in soil using universal extractants

Extractant used	Experimental site						
	Damot Sore	Boloso Bombe	Damot Pulasa	Humbo	Haramaya	Babile	Dire Dawa
0.01 M CaCl ₂	1.26	1.72	1.41	1.60	1.85	1.23	3.07
0.01 M BaCl ₂	2.24	3.00	1.85	2.01	5.14	2.10	4.11
0.1 M BaCl ₂	0.91	0.86	1.37	3.29	2.07	0.79	2.02
0.02 M SrCl ₂	1.55	0.56	7.40	7.00	8.46	6.24	14.48
Mehlich 3	2.15	0.33	7.12	10.53	20.00	6.70	50.23
AB-DTPA	0.25	0.22	0.14	2.87	3.45	1.13	2.20
0.02 M SrCl ₂ to 0.025 M citric acid	1.77	0.96	8.24	10.00	26.95	7.20	18.10
0.02 M SrCl ₂ to 0.05 M citric acid	2.07	1.27	9.31	13.05	30.79	8.04	16.00
0.02 M SrCl ₂ to 0.075 M citric acid	2.36	1.65	10.34	18.23	39.85	8.57	15.06
0.02 M SrCl ₂ to 0.1 M citric acid	3.03	1.67	14.56	21.40	46.73	9.07	5.51

AB-DTPA: Ammonium bicarbonate diethylene tri ammine penta acetic acid

Correlation between universal extractants and concentrations of P and K in the leaves of soybean plant: Using universal extractants, largely different values of P were extracted from soils. The method of analytical determination of P also influenced P concentration in the extract (Matula, 2009). The relationships between a soil testing extractant and plant nutrient concentration should be an important parameter in the selection of a soil testing method (Steffens, 1994).

The amount of extractable P varied markedly depending on the soils and extractants used (Table 2). For Damot Sore district, the highest amount of P (3.03 mg kg⁻¹) extracted by 0.02 M SrCl₂ to 0.1 M citric acid extractant, whereas the lowest amount of P (0.25 mg kg⁻¹). For Boloso Bombe district, the highest (3 mg kg⁻¹) and the lowest (0.22 mg kg⁻¹) were extracted by 0.01 M BaCl₂ and AB-DTPA extractant, respectively.

Similarly, for Damot Pulassa, Humbo, Haramaya and Babile districts, the highest amount of P determined by 0.02 M SrCl₂ to 0.1 M citric acid extractant and the lowest amount extracted by AB-DTPA extractant for Damot Pulasa and Humbo sites. The 0.1 M BaCl₂ extractant desorbs the lowest amount for Haramaya, Babile and Dire Dawa experimental sites. For moderately alkaline soil (Dire Dawa Administrative Council), the highest amount (50.23 mg kg⁻¹) was extracted by Mehlich 3 extractant.

The differences among the P extraction methods probably arose from the fact that plant available P in the soil is not from a discrete fraction but from a continuum of fractions; extracting agents preferentially extract from different fractions depending on their reaction with soil components involved in P sorption. In addition, each extracting solution has a different ability to extract varying portions of soil P because they were targeted at different pools of soil P (Zhang *et al.*, 2004).

The correlation between P extracted by universal extractants and P concentration in the leaves of soybean plant was shown in Table 3. Correlation analysis revealed that the amounts of P determined by extractants were significantly and positively correlated to some of the extractants tested with the P concentration in the leaves of the soybean plant through the application of P₀K₀, P₀K_{21.5}, P₀K₄₃ and P₀K_{64.5} kg ha⁻¹.

Table 3: Correlation between P extracted by universal extractants and P concentration in the leaves of soybean plant

Rate (kg ha ⁻¹)	Nutrient	Correlation coefficient (r)	CaCl ₂ (0.01 M)	BaCl ₂ (0.01 M)	BaCl ₂ (0.1 M)	SrCl ₂ (0.02 M)
P ₀ K ₀	P	P conc.	0.82*	0.70 ^{ns}	0.52 ^{ns}	0.92**
P ₀ K _{21.5}	P	P conc.	0.87**	0.68 ^{ns}	0.36 ^{ns}	0.88**
P ₀ K ₄₃	P	P conc.	0.89**	0.67 ^{ns}	0.41 ^{ns}	0.89**
P ₀ K _{64.5}	P	P conc.	0.85*	0.64 ^{ns}	0.37 ^{ns}	0.91**
		0.02 M SrCl ₂ to	0.02 M SrCl ₂ to	0.02 M SrCl ₂ to	0.02 M SrCl ₂ to	0.02 M SrCl ₂ to
Rate (kg ha ⁻¹)	Mehlich 3	AB-DTPA	0.025 M citric acid	0.05 M citric acid	0.075 M citric acid	0.1 M citric acid
P ₀ K ₀	0.93**	0.70 ^{ns}	0.86*	0.76*	0.65 ^{ns}	0.41 ^{ns}
P ₀ K _{21.5}	0.96***	0.55 ^{ns}	0.76*	0.63 ^{ns}	0.50 ^{ns}	0.24 ^{ns}
P ₀ K ₄₃	0.97***	0.58 ^{ns}	0.75*	0.63*	0.50 ^{ns}	0.23 ^{ns}
P ₀ K _{64.5}	0.96***	0.55 ^{ns}	0.76*	0.63 ^{ns}	0.50 ^{ns}	0.24 ^{ns}

*Significant at p<0.05; **Significant at p<0.01; ns: Non significant at p>0.05; AB-DTPA: ammonium bicarbonate diethylene tri ammine penta acetic acid

Table 4: Concentration of K (cmol kg⁻¹) in soil extracted by universal extractants

Extractants used	Experimental site						
	Damot Sore	Boloso Bombe	Damot Pulasa	Humbo	Haramaya	Babile	Dire Dawa
0.01 M CaCl ₂	1.26	1.72	1.41	1.60	1.85	1.23	3.07
0.01 M BaCl ₂	2.24	3.00	1.85	2.01	5.14	2.10	4.11
0.1 M BaCl ₂	0.91	0.86	1.37	3.29	2.07	0.79	2.02
0.02 M SrCl ₂	1.55	0.56	7.40	7.00	8.46	6.24	14.48
Mehlich 3	2.15	0.33	7.12	10.53	20.00	6.70	50.23
AB-DTPA	0.25	0.22	0.14	2.87	3.45	1.13	2.20
0.02 M SrCl ₂ to 0.025 M citric acid	1.77	0.96	8.24	10.00	26.95	7.20	18.10
0.02 M SrCl ₂ to 0.05 M citric acid	2.07	1.27	9.31	13.05	30.79	8.04	16.00
0.02 M SrCl ₂ to 0.075 M citric acid	2.36	1.65	10.34	18.23	39.85	8.57	15.06
0.02 M SrCl ₂ to 0.1 M citric acid	3.03	1.67	14.56	21.40	46.73	9.07	5.51

AB-DTPA: Ammonium bicarbonate diethylene tri ammine penta acetic acid

Phosphorus concentration values in the leaves of the soybean plant were positively and significantly correlated with available P concentration of soils obtained by 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3, 0.02 M SrCl₂ to 0.025 M citric acid and 0.02 M SrCl₂ to 0.05 M citric acid extractants tested in this study at P₀ K₀ treatment application (Table 3). The high correlation coefficient between P concentration in the leaves of the soybean plant and P extracted by Mehlich 3 extractant was supported by several previous research findings (Schlindwein and Gianello, 2008; Bortolon *et al.*, 2009, 2010; Steiner *et al.*, 2012). Among the universal extractants tested for correlation with P concentration by the plant, 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3 and 0.02 M SrCl₂ to 0.025 M citric acid extractants showed significant correlation with P₀K₀, P₀K_{21.5}, P₀K₄₃ and P₀K_{64.5} kg ha⁻¹ treatments applied. Therefore, 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3 and 0.02 M SrCl₂ to 0.025 M citric acid extractants could be used as an alternative method for determination of P in soils of the studied areas.

Exchangeable K value estimated by ten methods was shown in Table 4. The order of magnitude of extraction depends on the soil types and extractants used. Among the extractants tested, consistently higher amount of exchangeable K was extracted by 0.02 M SrCl₂ to 0.1 M citric acid extractant for Damot Sore, Damot Pulasa, Humbo, Haramaya and Babile districts. The 0.01 M BaCl₂ and Mehlich 3 extractant desorbs high amount of exchangeable K for Boloso Bombe district

Table 5: Correlation between K extracted by universal extractants and K concentration in the leaves of soybean plant

Rate (kg ha ⁻¹)	Nutrient	Correlation coefficient (r)	CaCl ₂ (0.01 M)	BaCl ₂ (0.01 M)	BaCl ₂ (0.1 M)	SrCl ₂ (0.02 M)
K ₀ P ₀	K	K conc.	0.69 ^{ns}	0.77*	0.78*	0.82*
K ₀ P ₂₃	K	K conc.	0.62 ^{ns}	0.68 ^{ns}	0.69 ^{ns}	0.75*
K ₀ P ₄₆	K	K conc.	0.68 ^{ns}	0.73 ^{ns}	0.70 ^{ns}	0.76*
K ₀ P ₆₉	K	K conc.	0.96***	0.92**	0.88**	0.89**
Rate (kg ha ⁻¹)	Mehlich 3	AB-DTPA	0.02 M SrCl ₂ to 0.025 M citric acid	0.02 M SrCl ₂ to 0.05 M citric acid	0.02 M SrCl ₂ to 0.075 citric acid	0.02 M M SrCl ₂ to 0.1 M citric acid
K ₀ P ₀	0.85*	0.94**	0.86*	0.89**	0.89**	0.86*
K ₀ P ₂₃	0.87**	0.93**	0.83*	0.85*	0.87**	0.84*
K ₀ P ₄₆	0.88**	0.92**	0.84**	0.84*	0.87**	0.84*
K ₀ P ₆₉	0.80*	0.83*	0.90**	0.88**	0.89**	0.89**

*Significant at p<0.05, **Significant at p<0.01, ***Significant at p<0.001, ns: Non significant at p>0.05, AB-DTPA: Ammonium bicarbonate diethylene tri ammine penta acetic acid

and Dire Dawa Administrative Council, respectively. Generally acidic reagents were shown to be more efficient in extracting K from soils with small amounts of soluble and rapidly exchangeable K (Doll and Lucas, 1973).

The closest correlations between universal extractants soil tests and plant leaves concentration were found for K. The values of correlation coefficients were similar for some of the extractants tested (Table 5). Correlation analysis revealed that the amounts of K determined by extractants were significantly and positively correlated to some of the extractants tested with the K concentration in the leaves of the soybean plant through the application of K₀ P₀, K₀ P₂₃, K₀ P₄₆ and K₀ P₆₉ kg ha⁻¹ treatments.

The AB-DTPA extractants showed very strong and positive correlation coefficients at p<0.01 significance level than the other extractants tested. However, potassium concentration values in the leaves of the plant were also positively and significantly correlated at p<0.05 and at p<0.01 level of significance with K concentration of soils obtained by 0.02 M SrCl₂, Mehlich 3, 0.02 M SrCl₂ to 0.025 M citric acid, 0.02 M SrCl₂ to 0.05 M citric acid, 0.02 M SrCl₂ to 0.075 M citric acid and 0.02 M SrCl₂ to 0.1 M citric acid extractants tested in this study at K₀ P₀, K₀ P₂₃, K₀ P₄₆ and K₀ P₆₉ kg ha⁻¹ treatments applied. The results obtained from this study are in agreement with the finding by other researcher (Hanlon and Johnson, 1984) who reported significant correlation with Mehlich 3 and AB-DTPA extractants in determining available K for soybean in Okluhama soils. Grzebisz and Oertli (1993) found that AB-DTPA and Mehlich 3 extractants were good indices for K availability in soybean for West Switzerland soils.

CONCLUSION

Among the universal extractants tested for correlation with P concentration in the leaves of soybean plant, 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3 and 0.02 M SrCl₂ to 0.025 M citric acid extractants showed significant correlation with P₀ K₀, P₀ K_{21.5}, P₀ K₄₃ and P₀ K_{64.5} kg ha⁻¹ treatments applied. Therefore, 0.01 M CaCl₂, 0.02 M SrCl₂, Mehlich 3 and 0.02 M SrCl₂ to 0.025 M citric acid extractants could be used as an alternative method for determination of P in soils of the studied areas.

The AB-DTPA extractants showed very strong and positive correlation coefficients at p<0.01 significance level than the other extractants tested for K concentration in the leaves of the soybean plant. However, this study has also shown that among the universal extractants tested,

0.02 M SrCl_2 , Mehlich 3, 0.02 M SrCl_2 to 0.025 M citric acid, 0.02 M SrCl_2 to 0.05 M citric acid, 0.02 M SrCl_2 to 0.075 M citric acid and 0.02 M SrCl_2 to 0.1 M citric acid extractants can be used for K determination in soils because of high correlation coefficients with K concentration in the leaves of the soybean plant.

This study has shown that, the soybean plant (Awassa-95) variety responds to the application of K fertilizer in soils of the studied areas. Thus, K is not deficient in Ethiopian soils must be removed. In parallel, the issue of K must be revisited. Moreover, further research is recommended for the field application of the treatments to validate the results of the green house pot experiment.

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REFERENCES

- ARC, 2004. Improved soybean varieties and cultural practices. Production Manual Prepared in Collaboration with Ethiopian Agricultural Research Organization, Awassa Research Center, Awassa, Ethiopia.
- Alfaro, M.A., S.C. Jarvis and P.J. Gregory, 2003. The effect of grassland soil managements on soil potassium availability. *J. Soil Sci. Plant Nutr.*, 3: 31-41.
- Anderson, J.M. and J.S.I. Ingram, 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods*. 2nd Edn., Oxford University Press, Wallingford, UK., ISBN-13: 978-0851988214, Pages: 240.
- Anonymous, 1993. Soil chemical analysis. Improvement of Soil Services for Agricultural Development, Ministry of Natural Resources Development and Environmental Protection, UNDP, FAO, Addis Ababa, Ethiopia.
- Bhonsle, N.S., S.K. Pal and G.S. Sekhon, 1992. Relationship of K forms and release characteristics with clay mineralogy. *Geoderma*, 54: 285-293.
- Boke, S., 2004. Soil phosphorus fractions as influenced by different cropping systems in Andosols and Nitosols in Kembata-Tembaro and Wolayta Zones, SNNPRS. M.Sc. Thesis, Alemaya University, Ethiopia.
- Bortolon, L., J.A. Schlindwein and C. Gianello, 2009. Soil phosphorus and potassium extractant in soils under no tillage. *Ciencia Rural*, 39: 2400-2407.
- Bortolon, L., C. Gianello and J.L. Kovar, 2010. Phosphorus availability to corn and soybean evaluated by three soil-test methods for Southern Brazilian soils. *Commun. Soil Sci. Plant Anal.*, 42: 39-49.
- Dahnke, W.C. and R.A. Olson, 1990. Soil Test Correlation, Calibration and Recommendation. In: *Soil Testing and Plant Analysis*, Westerman, R.L. (Ed.). 3rd Edn., Soil Science Society of America, Madison, Wisconsin, pp: 45-71.
- Doll, E.C. and R.E. Lucas, 1973. Testing Soils for Potassium, Calcium and Magnesium. In: *Soil Testing and Plant Analysis*, Walsh, L.M. and J.D. Beaton (Eds.). Soil Science Society of America, Madison, WI, USA., pp: 133-151.

- Donald, B., 2012. Measuring soil pH. Department of Forest and Natural Resources Management, State University of New York College of Environmental Science and Forestry, Syracuse, NY., USA, pp: 315-470.
- Ezeh, K.N., A.M. Omogoye and E.A. Akinrinde, 2007. Aluminum influence on performance of some Cowpea (*Vigna unguiculata*) varieties on a Nigerian Alfisol. *World J. Agric. Sci.*, 3: 517-522.
- Fageria, N.K., 2009. The Use of Nutrients in Crop Plants. CRC Press, Boca Raton, Florida.
- Freese, D., R. Lookman, R. Merckx and W.H. Van Riemsdijk, 1995. New method for assessment of long-term phosphate desorption from soils. *Soil Sci. Soc. Am. J.*, 59: 1295-1300.
- Giller, K.E. and K.E. Dashiell, 2007. *Glycine max* (L.) Merrill. In: Plant Resources of Tropical Africa, Van Der Vossen, H.A.M. and G.S. Mkamilo (Eds.). Backhuys Publishers, Wageningen, Netherlands, pp: 74-78.
- Grzebisz, W. and J.J. Oertli, 1993. Evaluation of universal extractants for determining plant available potassium in intensively cultivated soils. *Commun. Soil Sci. Plant Anal.*, 24: 1295-1308.
- Hanlon, E.A. and G.V. Johnson, 1984. Bray/Kurtz, Mehlich III, AB/D and ammonium acetate extractions of P, K and MG in four oklahoma soils. *Commun. Soil Sci. Plant Anal.*, 15 : 277-294.
- Hazelton, P.A. and B.W. Murphy, 2007. Interpreting Soil Test Results: What do all the Numbers Mean? Csiro Publishing, Australia, ISBN-13: 9780643092259, Pages: 152.
- Hedley, M.J., J.J. Mortvedt, N.S. Bolan and J. Keith Syers, 1995. Phosphorus Fertility Management in Agroecosystems. In: Phosphorus in the Global Environment: Transfers, Cycles and Management, Tiessen, H. (Ed.). Chapter 5, John Wiley and Sons, New York, USA., ISBN-13: 9780471956914, pp: 59-92.
- Ishibashi, Y., H. Matsuo, Y. Baba, Y. Nagafuchi, T. Imato and T. Hirata, 2004. Association of manganese effluent with the application of fertilizer and manure on tea field. *Water Res.*, 38: 2821-2826.
- Jones, Jr. J.B., 2003. Agronomic Handbook: Management of Crops, Soils and their Fertility. CRC Press Inc., Boca Raton, FL., USA., ISBN-13: 9781420041507, Pages: 450.
- Kochian, L.V., M.A. Pineros and O.A. Hoekenga, 2005. The physiology, genetics and molecular biology of plant aluminum resistance and toxicity. *Plant Soil*, 274: 175-195.
- Lindsay, W.L. and P.M. Walthall, 1996. The Solubility of Aluminum in Soils. In: The Environmental Chemistry of Aluminum, Sposito, G. (Ed.). CRC Press, Inc., Boca Raton, FL., pp: 333-361.
- Lupwayi, N.Z. and I. Haque, 1996. Phosphorous: A prerequisite for increased productivity of forage and browse/free legumes in the Ethiopian highlands. Proceedings of the 2nd Conference of the Ethiopian Society of Soil Science, October 8-11, 1996, Addis Ababa, Ethiopia.
- Makoi, J.H.J.R., S. Bambara and P.A. Ndakidemi, 2013. Rhizobium inoculation and the supply of molybdenum and lime affect the uptake of macroelements in common bean (*P. vulgaris* L.) plants. *Australian J. Crop Sci.*, 7: 784-793.
- Matula, J., 2009. A relationship between multi-nutrient soil tests (Mehlich 3, ammonium acetate and water extraction) and bio-availability of nutrients from soils for barley. *Plant Soil Environ.*, 55: 173-180.
- Mekaru, T. and G. Uehara, 1972. Anion adsorption in ferruginous tropical soils. *Soil Sci. Soc. Am. J.*, 36: 296-300.

- Moore, G., 2001. Soil Guide: A handbook for understanding and managing agricultural soils. A Joint National Landcare and Agriculture Western Australia Project, Bulletin No. 4343, July 2001, Australia, pp: 1-381.
- Okalebo, J.R., K.W. Gathua and P.L. Woomer, 2002. Laboratory Methods of Soil and Plant Analysis a Working Manual. 2nd Edn., TSBF-CIAT and SACRED Africa, Nairobi, Kenya.
- Owuor, P.O., F.O. Gone, D.B. Onchiri and I.O. Jumba, 1990. Levels of aluminium in green leaf of clonal teas, black tea and black tea liquors and effects of rates of nitrogen fertilizers on the aluminium black tea contents. Food Chem., 35: 59-68.
- SAS, 2004. SAS/STAT User's Guide: Version 9.1.3. SAS Institute, Cary, NC.
- Sample, E.C., R.J. Soper and G.J. Racz, 1980. Reaction of Phosphate Fertilizers in Soils. In: The Role of Phosphorus in Agriculture, Khasawneh, F.E., E.C. Sample and E.J. Kamprath (Eds.). American Society of Agronomy, Madison, WI., USA.
- Schlindwein, J.A. and C. Gianello, 2008. Calibration of phosphorus extraction methods in soils cultivated under no-tillage. Revista Brasileira Ciencia Solo, 32: 2037-2049.
- Steffens, D., 1994. Phosphorus release kinetics and extractable phosphorus after long-term fertilization. Soil Sci. Soc. Am. J., 58: 1702-1708.
- Steiner, F., M.C. Lana, T. Zoz, J.F. Frandoloso and R. Fey, 2012. Extraction methods and availability of phosphorus for soybean in soils from Parana State, Brazil. Ciencias Agrarias, 33: 1005-1014.
- Stevenson, F.J., 1986. Cycles of Soil Carbon, Nitrogen, Phosphorus, Sulfur and Micronutrients. John Wiley and Sons, New York, USA., Pages: 380.
- Stoorvogel, J.J., E.M.A. Smaling and B.H. Janssen, 1993. Calculating soil nutrient balances in Africa at different scales. Nutr. Cycl. Agroecosyst., 35: 227-235.
- Uehara, G. and G.P. Gillman, 1981. The Mineralogy, Chemistry and Physics of Tropical Soils with Variable Charge Clays. Westview Press, Colorado, ISBN-13: 9780891584841, Pages: 170.
- Van Raij, B., 1994. New diagnostic techniques, universal soil extractants. Commun. Soil Sci. Plant Anal., 25: 799-816.
- Van Reeuwijk, L.P., 1992. Procedures for Soil Analysis. 3rd Edn., International Soil Reference and Information Center, Wageningen, The Netherlands.
- Waskom, R.M., T. Bauder, J.G. Davis and A.A. Andales, 2012. Diagnosing saline and sodic soil problems. Colorado State University Extension, May 2012, Fort Collins, Colorado.
- Wijnands, J.H.M., N.D. Gurmesa, J.C.M. Lute and E.N. Loo, 2011. Ethiopian Soya Bean and Sunflower Value Chains: Opportunities and Challenges. LEI Wageningen UR, The Hauge, Netherlands, ISBN-13: 9789086155057, Pages: 128.
- Zhang, M., R. Wright, D. Heaney and D. Vanderwel, 2004. Comparison of different phosphorus extraction and determination methods using manured soils. Can. J. Soil Sci., 84: 469-475.
- Zhang, Q.C., G.H. Wang, Y.K. Feng, P. Qian and J.J. Schoenau, 2011. Effect of potassium fertilization on soil potassium pools and rice response in an intensive cropping system in China. J. Plant Nutr. Soil Sci., 174: 73-80.